NETWORKING TECHNOLOGIES FOR THE DISN

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1. INTRODUCTION

In the face of ever expanding needs for information to the warfighter, the Defense Information Systems Network (DISN) is confronted with a dynamic picture of requirements. Higher capacity and more sophisticated network technologies have evolved and are still evolving to meet these growing requirements. In this article, we discuss three networking technologies, and the relevance of each to the DISN mission. Specifically, we will address Gigabit Ethernet, and Gigabit IP switching and routing, and Asynchronous Transfer Mode (ATM).

We begin with a description of the DISN as the DOD's consolidated worldwide telecommunications infrastructure portion of the Defense Information Infrastructure. DISN is DOD's end-to-end information transfer network, which supports military operations. The DISN consists of three principle blocks: the sustaining base block, the long haul block and the deployed block. DISN and the DII need to bring information superiority to the warfighter. Figure 1 illustrates a simple picture of the DISN. The important points of this illustration are that:

- The consumers of this infrastructure are warfighters and
- All of these customers must be able, to an ever-increasing degree, to exchange information with each other.

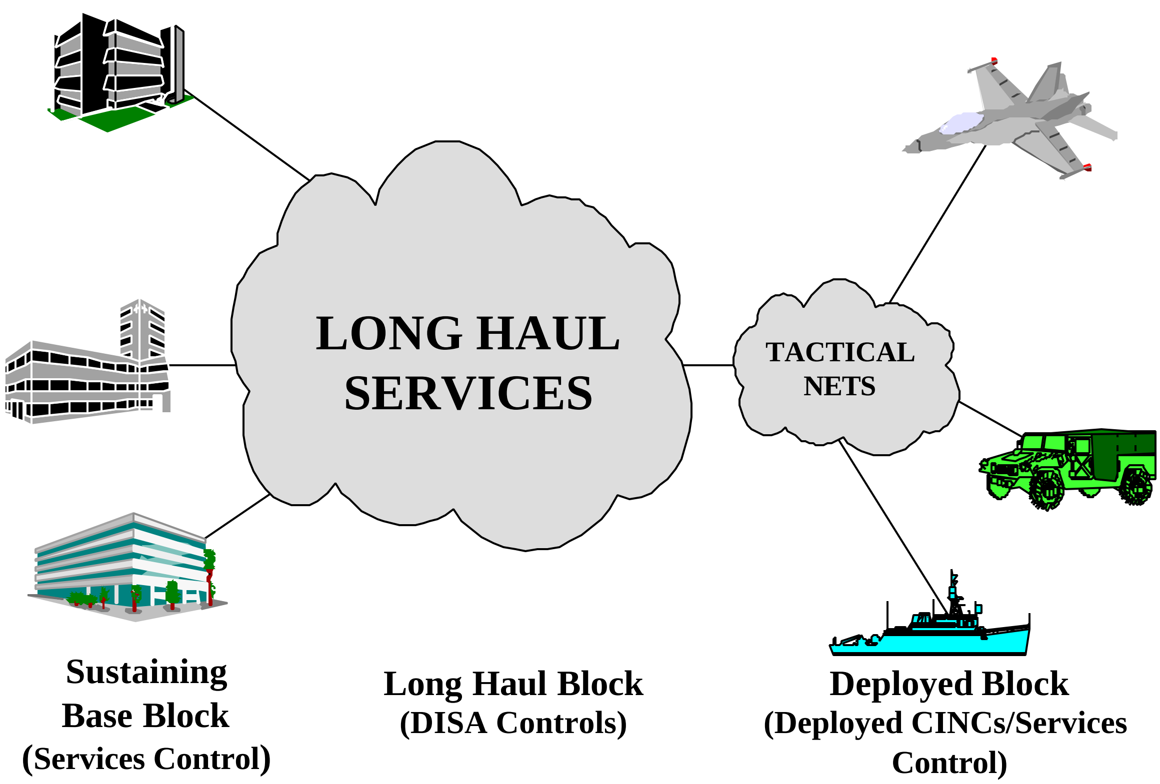


Figure 1 . Operational Building Blocks for End-to-End DISN

DISA is responsible for providing and managing the long haul block, and the connections to the sustaining base block and the deployed block. The Commanders in Chief, the Military Departments, Defense Agencies and other customers are responsible for providing and managing their deployed block and their sustaining base block, including processing platforms, tactical/deployed elements, local area networks, and private branch exchanges. The objective of DISN is to provide DOD's worldwide protected network allowing the warfighters to plug in, and push or pull information in a seamless, interoperable and global network. We next describe the known and evolving requirements for services that are driving the architecture, design and implementation of the DISN. Following that, we discuss these new technologies and their individual characteristics. Finally, we compare the technologies to the requirements and draw some conclusions as to the utility of each technology for use in the DISN.

The Bottom Line… This article is intended to shed light on several high-performance networking technologies and their application in the DISN. It is the overall opinion of DISA that:

- Gigabit Ethernet is primarily an IP-oriented LAN technology and is no better suited to a WAN or MAN environment than are existing lower speed Ethernet technologies. The selection of Gigabit Ethernet for a campus technology should be based on cost and requirements considerations. Generally, implementation of Gigabit Ethernet in a LAN may be less costly than implementation of ATM. However, the choice of Gigabit Ethernet must be made with the full understanding that emerging native ATM requirements as well as circuit emulation requirements (to replace TDM) may force the installation of other LANs in parallel to Gigabit Ethernet. Those requirements will be described in detail in this paper.

- Gigabit IP switches and routers may also have a place in LAN environments based upon the same cost/requirement considerations that apply to Gigabit Ethernet. These technologies are also promising candidates for high performance IP backbone networks. However, as powerful and advanced as these technologies are, they suffer from the same fundamental drawback of Gigabit Ethernet. That is, although they support IP very well, they ONLY support IP service, and not native ATM or circuit emulation service. A LAN or WAN choice in favor of Gigabit IP switches or routers must be made with the full understanding that emerging non-IP requirements may force the installation of one or more parallel LANs or WANs meet those requirements. Those requirements will be described in detail in this paper.

- ATM is the only current technology that can be adapted to support all known and emerging networking requirements for the warfighter. This paper will describe technologies, methods and standards that exist for interfacing all known or projected types of services (including IP) onto ATM. Therefore, ATM is the preferred technology for the DISN long haul infrastructure. With a single, integrated ATM WAN, the DISN can extend services seamlessly into all of the warfighter's various domains.

2. IP VS ATM.

Before proceeding further, it is necessary to address the common myth that good network engineers must choose between Internet Protocol (IP) and Asynchronous Transfer Mode (ATM). Table 1 illustrates the widely accepted Open System Interconnect (OSI) model for data communications. Although there is no precise way to assign IP or ATM to exactly one of these layers, it is generally recognized that Internet Protocol exists primarily in the NETWORK layer (layer 3) while ATM exists primarily in the DATA LINK layer (Layer 2).

Table 1. Protocol Stacks and the OSI Model

OSI LAYER	EXAMPLES OF USAGE
APPLICATION Layer 7	Application Programs and Protocols for File Transfer, Email, Browsers, etc
PRESENTATION Layer 6	Telnet, File Transfer Protocol (FTP), Simple Mail Transport Protocol (SMTP), etc
SESSION Layer 5	
TRANSPORT Layer 4	Transmission Control Protocol (TCP) Unacknowledged Datagram Protocol (UDP)
NETWORK Layer 3	Internet Protocol (IP)
DATA LINK Layer 2	Ethernet, Token-Ring, FDDI, ATM, Frame Relay, etc
PHYSYCAL Layer 1	Transmission Media: Twisted Pair, Coax, Fiber Optic, Wireless Media, etc

IP, by virtue of its having become the de facto standard for the overwhelming majority of contemporary applications, must be supported on ANY network, regardless of the choice of layer 2 approach. Because of this, there are a number of standards-based methods for supporting IP on an ATM infrastructure, as well as standards-based methods for supporting IP over other layer 2 protocols.

Many applications employ all or most of the seven layers of the protocol stack; however, other applications employ only a few layers. For example, a typical application like Email or a web browser will use the entire stack. However, as discussed later, there are fundamentally new evolving devices and applications that the DISN must serve that are bypassing portions of the stack for reasons such as guaranteed Quality of Service. Some examples include high definition graphics, high definition video, streaming time sensitive traffic and “executive quality” encrypted video teleconferencing. Table 2 illustrates that a growing collection of such applications are NOT utilizing those portions of the OSI stack related to traditional Transport and Networking. Many of these use Application Program Interfaces (APIs) to interface directly into networks at the layer 2 level using ATM as the Data Link Layer Protocol. These are typically called “Native ATM” applications.

Table 2 . Native ATM Applications Bypass the OSI Stack

OSI LAYER	EXAMPLES OF USAGE
APPLICATION Layer 7	"Native ATM" Application (High performance Video, Voice over ATM, etc)
PRESENTATION Layer 6	DIRECT ATM API
SESSION Layer 5	
TRANSPORT Layer 4	
NETWORK Layer 3	
DATA LINK Layer 2	ATM Signaling, ILMI, AAL stack
PHYSICAL Layer 1	Transmission Media: Twisted Pair, Coax, Fiber Optic, Wireless Media, etc

OSI analysis reveals one startling and important fact. Although IP can be transported comfortably on almost any network, regardless of the layer 2 protocol selected (including ATM), a network that forces users to interface with it at a higher layer (say layer 3 IP) cannot support native ATM traffic. The Global Grid community envisions 10,000 high performance desktops which will employ native ATM for imagery; this represents a small, albeit important, fraction of all DOD users. For other users who only want to do TCP, UDP, WEB, EC or even voice or video over IP, an IP network interface may be perfectly acceptable.

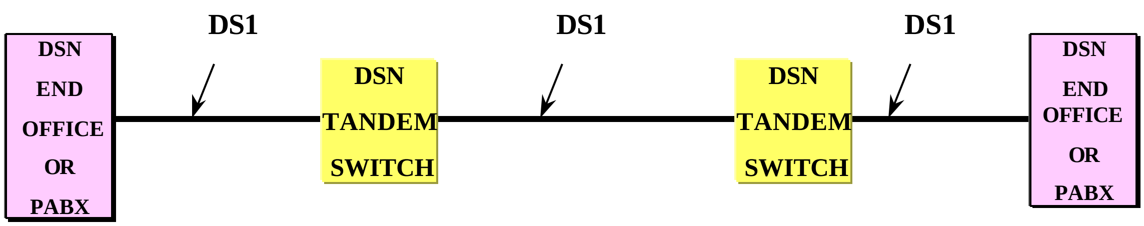
3. THE REQUIREMENTS

Even under the best of circumstances, it is not easy to predict the needs of DOD users far into the future; however, much is known today and much about the future can be said with some confidence. We know that users are energetically applying new applications and technologies to help them as warfighters in everything from imagery to tactical battlefield communications. Joint Vision 2010 represents a concerted effort by the DOD community to implement and exploit a worldwide information infrastructure to meet the growing needs for Defense in Depth which calls for encrypted circuits, secure control, firewalls, host and network monitoring, PKI, etc. We have come to call the engineering view of this vision the "Global Grid". The Global Grid is the world's only "security based" information infrastructure. It is standards driven, interoperable, scaleable and commercially derived. It consists of communications, computing, storage, visualization and applications. Global Grid is considered to be the seamless integration of space and terrestrial assets into a single warfighting system. Global Grid is considered by many to be the key to information superiority for the United States. The Global Grid calls for the DISN to provide a non-blocking ATM switching capability to move imagery rapidly around the Globe. It calls for multimedia capability integrating voice, data, and video with quality of service to enable global collaboration and simulation. It calls for end-to-end security. It requires high quality visualization through HDTV.

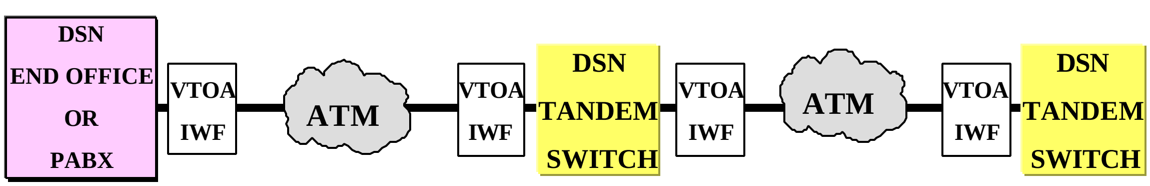
Visions are fine, but by themselves, they don't constitute a very sharp picture of the types of services the warfighter will need. What are the REAL requirements? In the next few paragraphs, we examine those requirements as best we can foresee them. We'll also extrapolate a bit on how they will evolve in the next few years.

3.1.1 Existing DISN Services

3.1.1.1 VOICE (DSN). Voice services have been the mainstay of DOD. Plain Old Telephone Service (POTS) continues to be in great demand. The Defense Switched Network (DSN) has evolved to a modern carrier-class worldwide network using all-digital technologies. Recent upgrades have allowed DSN to offer ISDN services as well as other modern features. The current architecture of the DSN uses dedicated "tandem switches" in the backbone connected by dedicated point-to-point trunks. End office switches or PABXs provide access to this backbone network via dedicated trunks.

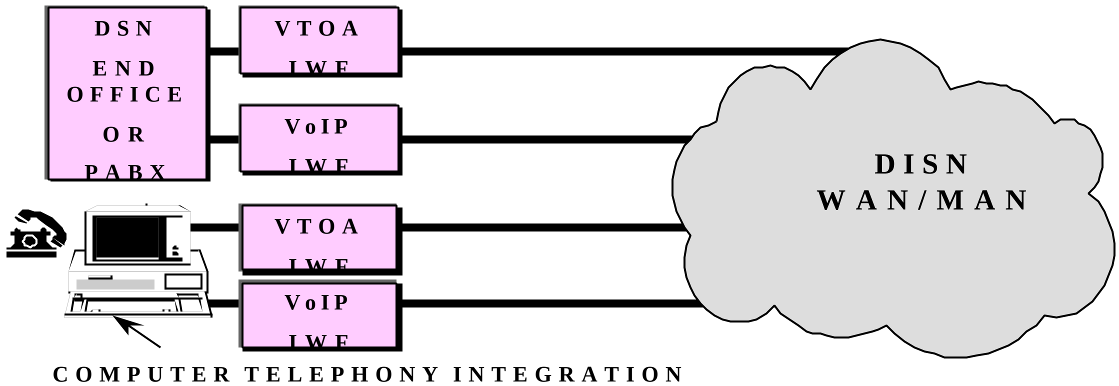


In the next few years, this architecture will change to exploit the advantages of new technology and shared-bandwidth backbones. Initially, the existing switches could be interconnected using Circuit Emulation Services (CES) over ATM networks. However, this Constant Bit Rate (CBR) service would represent little gain in effective bandwidth usage over existing 64kbps-based Time Division Multiplexing systems. A more desirable next step is the interconnection of interswitch trunking systems that do voice compression and other voice processing algorithms (e.g., silence suppression). This "Interworking Function" exists today and is being certified for use on the DSN. This is one way of doing Voice Telephony over ATM (VTOA).

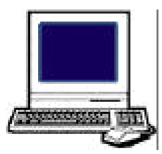


In addition to Voice Telephony over ATM, Voice over IP (VoIP) is becoming even more widely accepted as a very attractive method to migrate from traditional voice systems into an integrated voice/data system. VTOA and VoIP will likely become the dominant technologies in the next decade. Coupled with Computer Telephony Integration, which refers to systems that enable a computer to act as a call center, accepting incoming calls and routing them to the appropriate device or person, these technologies will allow full feature telephone services from workstations or as stand-alone devices.

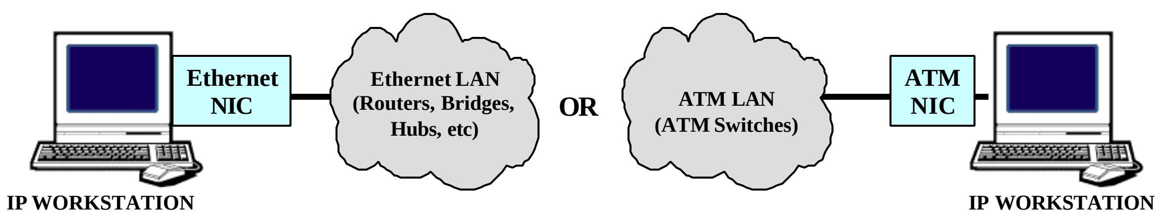
Ultimately, VTOA and VOIP will allow the replacement of the tandem switches with a fully network-centric voice service.



3.1.1.2 IP DATA Sensitive But Unclassified (SBU) (NIPRNET). Most every computer or



workstation in the world, which communicates outside itself, does so by using IP-based applications. Email and web browsers are ubiquitous. The NIPRNET is the DOD's "Intranet" for supporting Unclassified IP services. There are a variety of ways of supporting IP at the local area (LAN) and wide area (WAN) levels. At the LAN, workstations can be configured with many different types of "Network Interface Cards" (NICs) depending on the LAN Data Link (OSI Layer 2) architecture. These NICs can be, for example, Ethernet (up to Gigabit), FDDI, ATM, or others. The Local Area Network devices will be determined



by the nature of the LAN as shown here.

At the Wide Area (WAN) level, an Ethernet LAN can transition to a router-based WAN. An Ethernet LAN can also transition to an ATM LAN by use of a conversion device or Interworking Function (IWF). In the case of an Ethernet, the IWF must do a physical conversion from Ethernet to ATM as well as performing the IP internetworking function. Today, this IP internetworking function is typically done using LAN Emulation (LANE), but will evolve in the future to Multiple Protocol over ATM (MPOA) and Multiple Protocol Label Switching (MPLS). This IWF performs translation functions from IP addresses to ATM layer 2 addresses and performs other functions such as route determination. It should be noted that ATM-equipped LANs that support IP applications must also use some sort of IP internetworking protocol to convert the IP destination address to an ATM address.

This protocol is generally implemented in the workstation or server attached to the ATM LAN. Figure 2 shows how some of these conversions work.

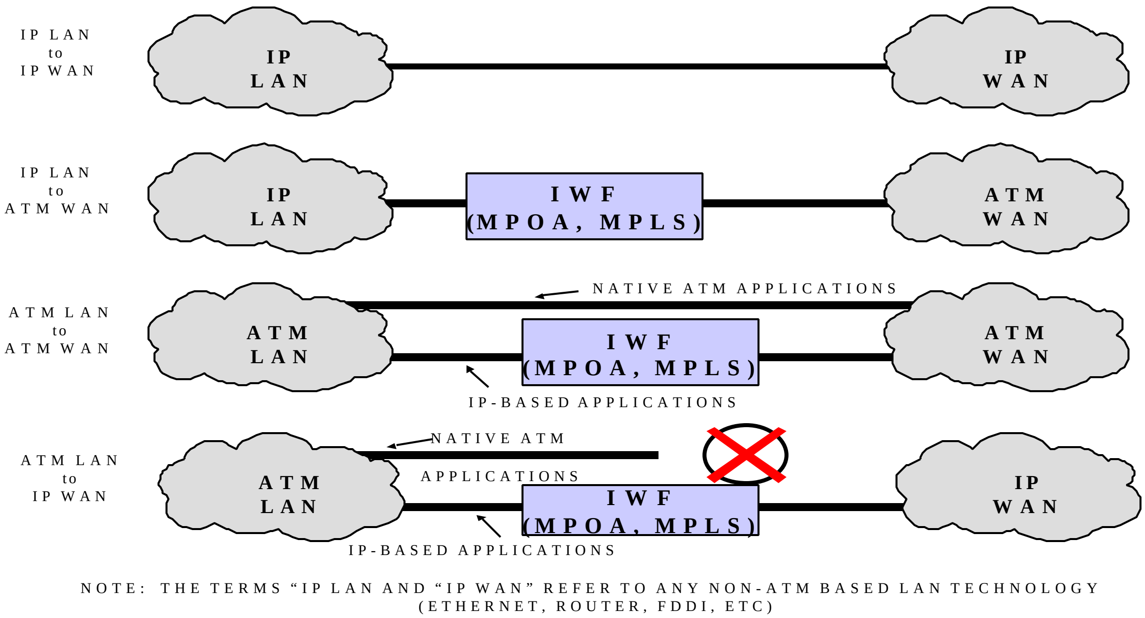


Figure 2. IP DATA ACROSS LANs and WANs

3.1.1.3 IP DATA Classified (SIPRNET). Classified IP data is currently supported on the DISN Secret IP Router Protocol Network (SIPRNET). For all practical purposes, this network functions exactly like UNCLASSIFIED IP networks at the LAN level. That is, LANs can be Ethernet, Router, FDDI, ATM or other. The only difference at the LAN level is that, since these LANs are processing classified information, they are protected as "system high" RED LANs, with physical control and protection of the physical transmission media. The great difference with CLASSIFIED IP is at the WAN level. In order to classified IP data to travel across UNCLASSIFIED (or "BLACK") long haul networks it must be encrypted. Figure 3 illustrates several methods of interfacing classified IP data with WANs. Note that two types of encryption devices are introduced here. The IP encryption device is typically either a Network Encryption System (NES) or in the future a TACLANE. The maximum sustainable data rates of these devices is, for the NES on the order of about 1.5 MB/s; for the TACLANE when used in the IP mode, about 4-8 MB/s. Encryption of ATM (including ATM which is carrying IP) is done by the KG-75 FASTLANE. Current versions of FASTLANE operate at up to 155 MB/s with future versions expected to operate at rates up to 10 GB/s. The current SIPRNET is separate from the NIPRNET and uses link encryption; however, the Global Grid vision calls for one integrated network with security level separated by end-to-end encryption.

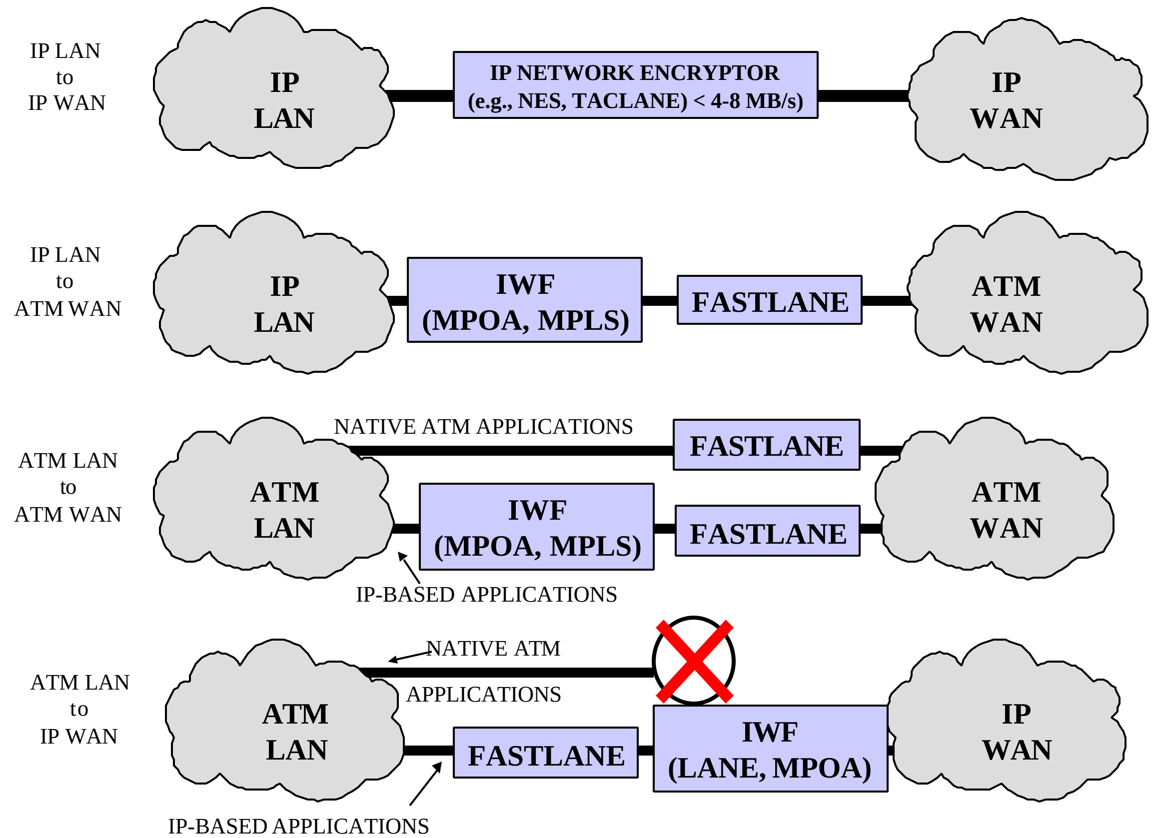
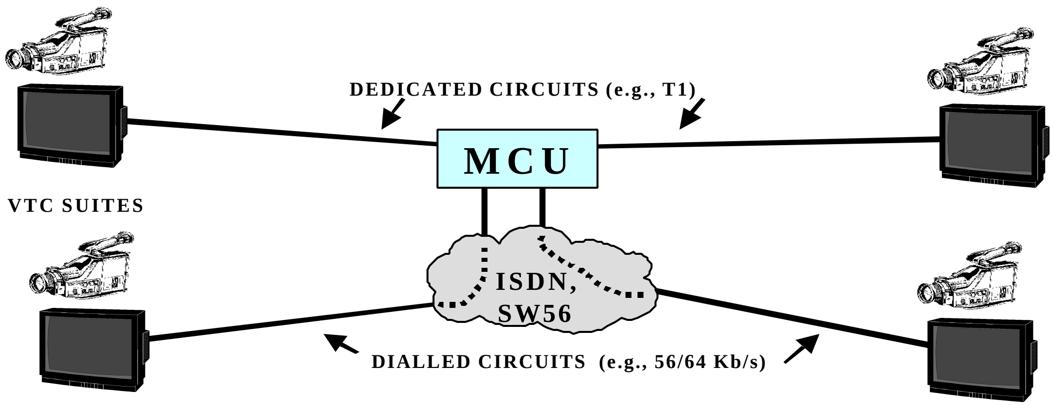


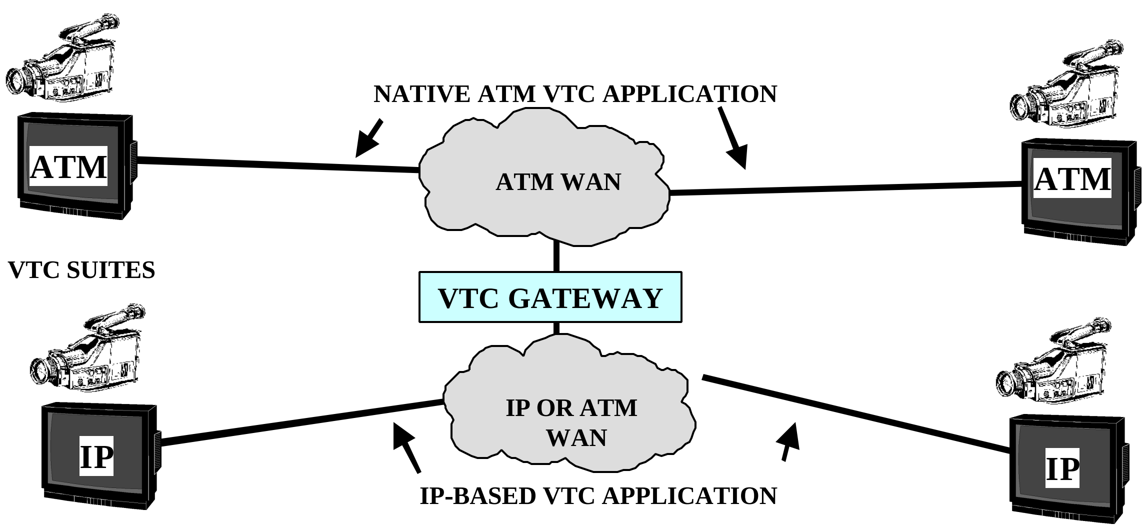
Figure 3. CLASSIFIED IP DATA OVER LANs and WANs

3.1.1.4 Defense Red Switched Network (DRSN). The DRSN is a carrier-class voice switched system supporting classified voice applications. In addition to standard "POTS" types of functions and features, the DRSN provides many advanced features supporting unique DOD requirements for command and control and survivability. Today's DRSN is a dedicated, stand-alone network comprised of switching systems interconnected by dedicated circuits that are encrypted on a full-period basis. It is envisioned that DRSN will use some of the same technologies as DSN (e.g., VTOA, VOIP, and end-to-end encryption) to become a part of the single integrated DISN of the Global Grid.

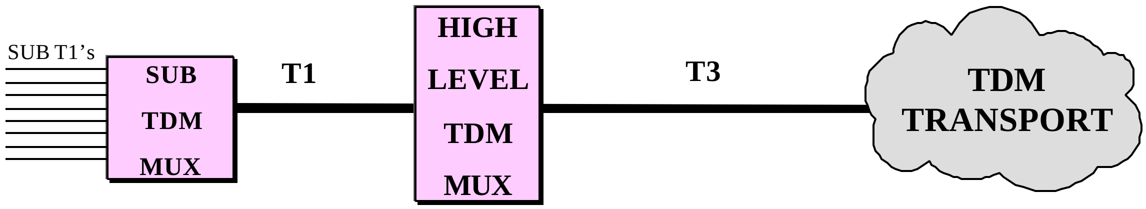
3.1.1.5 Video Teleconferencing (VTC). Today's DISN Video Teleconferencing Service uses largely dedicated high speed circuits or dial-up lower speed circuits connecting VTC "studios" with Video Conferencing Bridges called Multi-media Conferencing Units (MCUs).



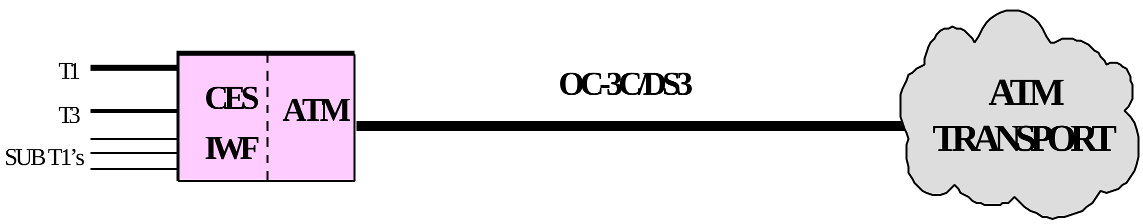
The technology to support this is mature and stable, but it does have limitations in terms of scalability and availability to the general DOD community. Newer network-centric technologies are emerging which will provide full-featured VTC services without dedicated circuits. Most of these systems are IP-based today and allow reasonable quality VTC to the desktop over any IP network. The emerging high performance desktop VTC applications as well as the "executive quality" VTC systems are often native ATM. Both of these technologies take advantage of networking services such as multicast and will ultimately minimize dependence on single point sensitive MCUs.



3.1.1.6 Circuit Services (e.g., T1, Synchronous EIA 530, etc). It is likely that synchronous circuit services will be required in the DISN for the foreseeable future. Although the trend is away from dedicated circuits as more users migrate to the types of network-oriented applications described here, many systems are still designed around a dependence on dedicated, constant data rate synchronous circuits. Today's circuit services are provided with intelligent Time Division Multiplexers (TDM). These systems are robust and efficient at supporting circuit services.



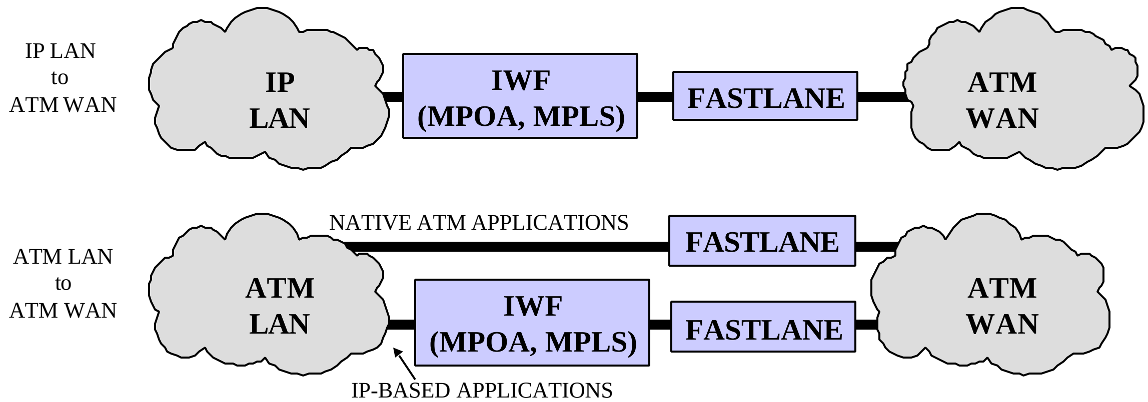
Supporting Circuit Services over data networks is problematic due to the stringent timing, synchronization and jitter requirements for most circuit services. With ATM technology, standards-based approaches exist for Circuit Emulation Service (CES) which can support these rigorous requirements. At the present time there is **no known** technology for supporting synchronous circuit services over an IP-based WAN infrastructure



3.1.2 Emerging DISN Services.

3.1.2.1 VERY High Speed streaming (e.g., HDTV at rates above 1Gbps) and very high speed file transfer. There are numerous emerging needs for new types of DISN services. This paper has mentioned in a generic way the emergence of "Native ATM" types of applications and the impact they will have on DISN LANs and WANs. Most existing and projected high performance streaming video is being developed to exploit the unique attributes of ATM networks that include guaranteed quality of service, controllable and predictable timing and synchronization and virtually unlimited and non-blocking throughput. The National Association of Broadcasters has chosen ATM as its choice for distribution of primary quality video within its member's networks. The DOD intelligence community is adopting ATM as its choice for distribution of primary imagery and other intelligence products as part of the Global Grid. Emerging "executive-quality" video and video conferencing applications tend to be native ATM as well. It is clear that, in the high performance market where controllable and predictable performance are critical, users are adopting ATM as their LAN and WAN technology choice.

3.1.2.2 High Speed Classified (>10 Mb/s). Perhaps the most severe driver for choice of a LAN or WAN technology remains the growing need to exchange classified information at high speeds. Modern classified information systems use many of the same applications that the unclassified systems use (Email, FTP, browsers, etc.). Most of these applications are IP-based. Even in a modest-sized classified enclave, the aggregate requirements for data flow across a wide area network can easily exceed 10 MB/s. However, as mentioned in paragraph 3.1.1.3, IP-based WAN encryption systems that exist or are being developed are limited to at most 4-8 Mb/s throughput. Consequently, a classified IP LAN (e.g., routers, bridges and Ethernets) are limited to data rates equal to, or less than, 4-8 MBPS when sending over a classified IP-only WAN. Note that a separate, classified IP network could be run system high with link encryption used between routers; however, the goal with DISN is a single unified network and this requires packet by packet encryption for an IP network or cell by cell encryption for an ATM network. The only existing higher speed alternative for a network-based encryptor is the KG75 Fastlane. This is an ATM cell-based encryptor and can currently support throughputs of up to 155 MB/s. Future releases of the KG75 will improve the throughput to up to 10 GB/s.



4. CANDIDATE DISN LAN/WAN/MAN BACKBONE TECHNOLOGIES

4.1 Gigabit Ethernet (IP-based layer 3 interface)

4.1.1 Concept. Gigabit Ethernet is a third generation Ethernet offering a simple, inexpensive, high bandwidth technology for LANs and campus networks. It offers a speed of 1000 MBPS (1 GBPS) that is fully compatible with existing Ethernets and provides seamless migration to higher speeds without impeding existing protocols or applications.

4.1.2 Implementation. Gigabit Ethernet, as denoted in the IEEE 802.3z standard, is 10 times faster than Fast Ethernet. Its instantiation is usually over fiber optics but it can be implemented on existing twisted pair cable over short distances.

4.1.3 Technological Advantages

- Similar technology and implementation as Ethernet and Fast Ethernet
- High Speed
- Proven reliability
- Scalable
- Interoperable with legacy systems
- Seamless for IP-based protocols and applications
- Multiple media types supported

4.1.4 Technological Disadvantages

- Distance limitations may apply (from 25m for UTP to 3000m for SMF)
- Not well suited for WANs due to higher latencies encountered

- Pre-Standard implementations may not interoperate
- Cannot support non-IP applications such as native ATM and circuit emulation services

4.1.5 Interoperability. In 1996, 82% of all networking equipment shipped was Ethernet. It is the most pervasive networking technology

4.1.6 Standardization. Gigabit Ethernet Alliance, IEEE 802.3z Gigabit Ethernet Standard (July 1998),

4.1.7 Applications

- LANs
- Building
- Campus.

4.2 Gigabit Switch Router (a.k.a. Gigabit Router, IP Switching)

4.2.1 Concept.

4.2.1.1 Gigabit Switch Routers (GSRs) are Layer 3 switches that perform high speed (70+ gigabit) routing for TCP/IP distributed architecture networks. Currently, GSRs support OC-48 interfaces with planned support for OC-192. GSRs provide ATM line cards to support seamless TCP/IP routing to ATM networks. Because GSRs are based on TCP/IP internetworking, they provide dynamic, redundant paths in the backbone and are interoperable with all well-known backbone and LAN technologies.

4.2.1.2 A variation of the GSR is the routing switch (RS). Whereas GSRs are classical routers that provide high-speed crossbar, non-blocking switching at Layer 3; RSs are Layer 2 switches that eliminate the performance penalty of Layer 3 switching. Essentially, RS's establish a route, in a distributed fashion, on initial packets and create dedicated paths through the network for all arriving packets with the same source destination pair. This capability is not unlike ATM technology and in some cases actually does the Layer 2 switching in ATM format. The discussion below addresses the classical GSR.

4.2.2 Implementation

4.2.2.1 GSRs have four fundamental elements including a route processor, switch fabric, forwarding engine, and line cards. These elements are described below and shown in Figure 4.

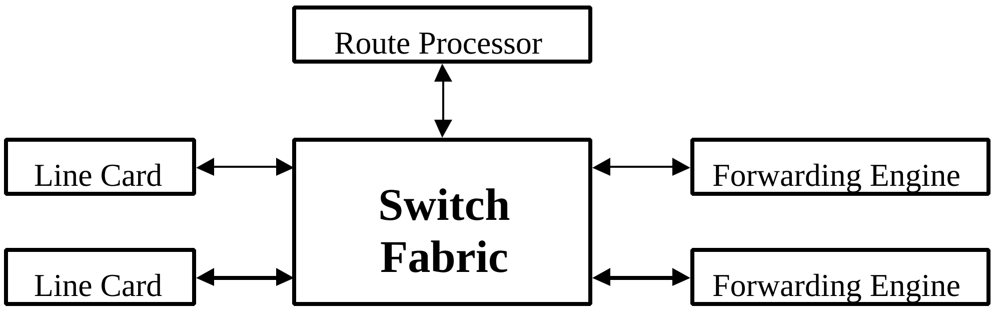


Figure 4. High-Speed Router Structure

Switching Fabric – a multi-gigabit, non-blocking crossbar-switching matrix that support multiple simultaneous connections at low latency and fast throughput. The switching fabric interconnects the various components of the gigabit router and offers much higher capacity than backplane architectures.

Forwarding Engine - inspects packet headers and determines outgoing linecard for a packet/cell.

Network (Route) Processor - runs the routing protocol and computes routing tables, which are copied to each of the forwarding engines. The processor also handles network management and special handling of packets.

Significant features supported by GSRs include:

- Standard Internet Routing Protocol support including RIP, OSPF, BGP, EIRGP[*]
- Multiple interface support for interoperability including SONET (to OC-192), ATM, Gigabit Ethernet, etc.
- Hardware based multicast for multimedia
- Support for VLAN technology
- Built to support Internet Protocol Next Generation (IPng), officially known as IPv6

4.2.3 Technological Advantages. GSRs have a number of significant technological advantages that should be considered when selecting technologies based on specified “provider” and “user” requirements. These advantages include:

- Implementation of TCP/IP as an internetworking technology resulting in a high degree of flexibility and interoperability, ease of integration with legacy systems and ease of migration to new technologies
- Dynamic interior and exterior routing algorithms and functionality to improve system level survivability
- Optimality of source to destination paths, through autonomous routing, and loading of bandwidth, i.e., reduced contention on limited WAN links, based on provider defined criteria
- Dynamic error detection and system reconfiguration and convergence in a short period of time
- Broadcast and multicast capabilities

- High bandwidth over SONET (OC-48 and OC-192)
- Ability to "reserve" and dedicate bandwidth via protocols such as RSVP
- Rich administrative features such as traffic filtering and reconfigurability
- Security implemented in the protocols

4.2.4 Technological Disadvantages. The use of GSRs has technological disadvantages as compared to other current technologies. These technical disadvantages must be weighed against provider and user needs. Technological disadvantages related to the IPv4 protocol suite may be improved with the deployment of IPv6. The disadvantages include:

- Require internal processing for Layer 3 switching, thus possibly incurring delays for real-time data. This is CPU speed and bandwidth dependent.
- No guarantee of quality of service as delivery is best effort. Protocols are being developed to support higher levels of QOS and priorities.
- Variable latency will occur in the backbone as a result of delays or multiple path routes requiring reassembling, and buffering of real-time data to prevent jitter.
- Management overhead could be significant in order to configure and maintain individual GSRs. However, day-to-day GSR operations are autonomous.
- Cannot support non-IP applications

4.2.5 Interoperability. GSRs are fully interoperable with well-known networking technologies. GSRs implement Layer 3 internet protocols that serve as the networking functionality of the TCP/IP stack. This characteristic makes them compatible with all known networking technologies that employ TCP/IP. Additionally, GSRs can incorporate direct Layer 2 interfaces with full support to these lower layers. This permits GSRs to serve as a backbone technology over SONET or an edge technology, to the backbone, to provide connectivity to a variety of network implementations including Ethernet variations, token rink, FDDI, ATM, etc.

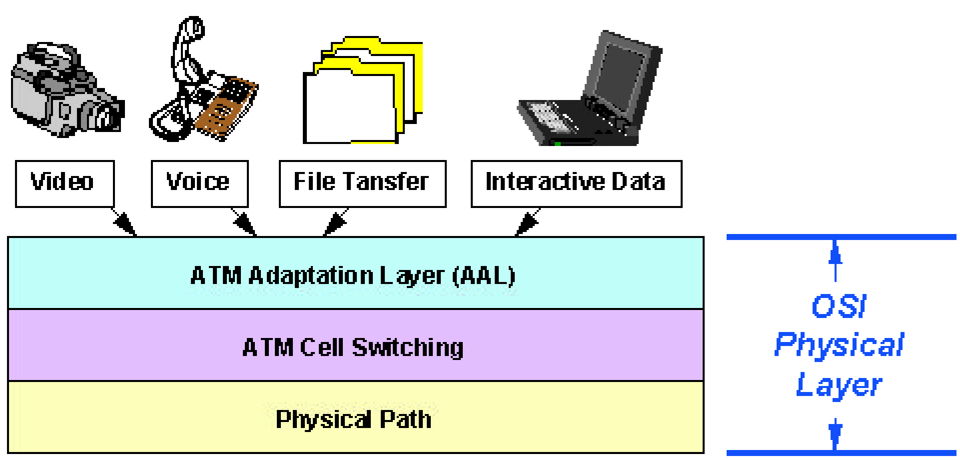
4.2.6 Standardization. GSRs are implemented based on Internet Protocol Standards IPv4 (Mature) and/or IPv6 (Maturing). The Internet Engineering Task Force (IETF) maintains the TCP/IP standards, known as RFPs. GSRs also support other standards at the interface level.

4.2.7 Security. GSRs provide for security implementation in the router. These security features include packet filtering based on user defined parameters and will include data encryption in the IP packet with IPv6. IPv6 will also provide additional security features in the protocol including authentication, data integrity and confidentiality.

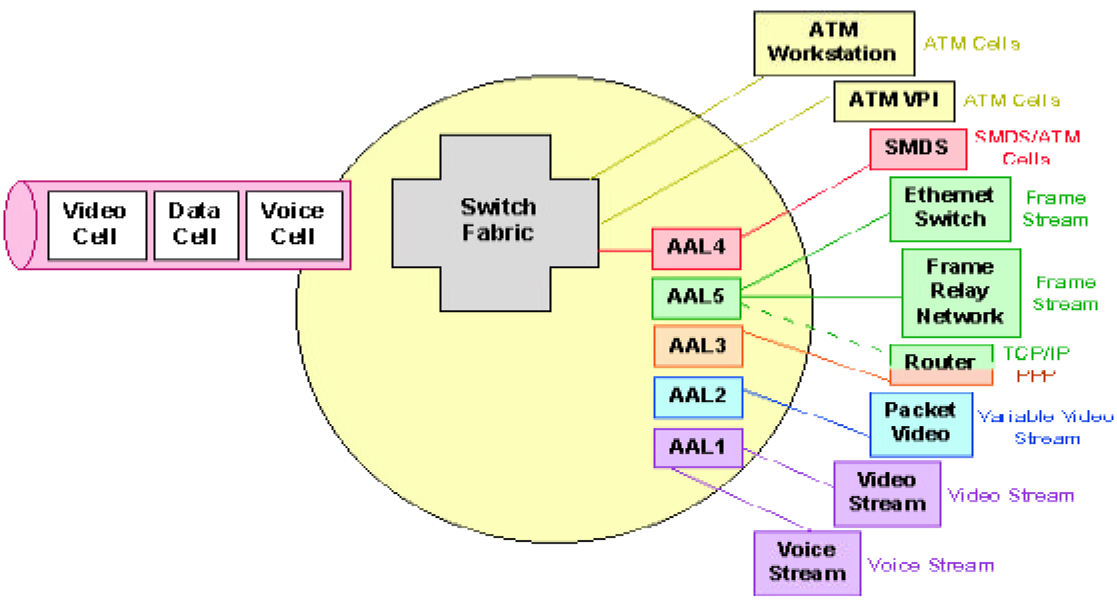
4.2.8 Applications. Because of the nature of GSRs and because they are TCP/IP-based, they lend themselves to virtually all levels of networking and internetworking except for non-IP applications. For pure IP applications, they could be implemented for a WAN backbone as well as an edge technology for a WAN. They are also an excellent choice for MAN, Campus, Intranet, or building IT architectures.

4.3 Asynchronous Transfer Mode (ATM)

4.3.1 Concept. ATM is a Layer 2 switching technology. It is designed around a fixed-length packet, or "cell" of 53 bytes. The driving concept behind ATM is to use "adaptation layers" to convert user services into a common format (cell) for transmission. All cells are identical in length and structure and contain routing and other identifying information in the first five "header" bytes of each cell. The result of this uniformity in cell structure means that ATM switches can be designed to switch at very high speeds.



4.3.2 Implementation. The structure of an ATM switch causes it to become, in essence, a cell queuing device for all types of traffic. As shown below, adaptation standards (called ATM Adaptation Layer or AAL) exist for almost any known type of requirement, including IP. This means that any ATM switch can support any of these requirements. ATM operates as a "connection-oriented" service somewhat analogous to telephone networks. ATM uses standards-based robust signaling for access to and routing control of the network.



4.3.3 Technological Advantages

- Operates at OSI Layer 2 making it independent of higher layer protocols and applications
- Connection-oriented allowing for advanced features such as guaranteed Quality of Service, end-to-end predictable performance, and synchronous applications
- Virtually unlimited speed. Current operational systems run at 40 GB/s non-blocking
- Virtually unlimited scalability using hierarchical network topologies and Private Network-to-Network Interface (PNNI) signaling
- Robust restoral of networks using PNNI
- Seamless for ALL protocols and applications
- Can support rigorous timing and synchronization requirements including distribution of precise timing

4.3.4 Technological Disadvantages

- May be more costly for equivalent performance in LAN environment
- Overhead for IP internetworking required (LANE, MPOA, MPLS)
- Cell encapsulation overhead may be troublesome for low bandwidth environments
- The protocols, signaling, configuration, and troubleshooting are extremely complex. Staff must learn a whole new technology, a time consuming and lengthy process. Experience in troubleshooting will be slow in coming, delaying outage resolution.

4.3.5 Interoperability. ATM is fully interoperable with all well-known networking technologies, including IP. The wealth of standards-based descriptions of Interworking Functions for ATM makes it easily one of the most flexible technologies for servicing different types of user requirements.

4.3.6 Standardization. Implementation, operation, management and interfaces for ATM are supported by several international standards bodies including the ATM Forum, The Internet Engineering Task Force, (IETF), and the International Telecommunications Union (ITU).

4.3.7 Security. ATM security is derived from on-going work in existing standards bodies such as the ATM Forum and IETF. The ATM Forum's Security Framework and Security Specification, coupled with IETF evolving standards for secure network management using SNMP will enable a comprehensive security framework for confidentiality, authentication, integrity protection and protection from denial of service for ATM systems.

5. COMPARING THE TECHNOLOGIES

5.1 ATM vs. Gigabit Ethernet. While ATM and Ethernet compete at the Local Area Network (LAN) level, they should be viewed as solutions to different problems. Ethernet will always be a fast-link (e.g. LAN) technology, not a WAN technology. In contrast, ATM was developed as an extremely efficient switching (WAN) technology and then evolved into a LAN technology. Ethernet's appeal is that local network managers understand it. However, ATM offers capabilities lacking in Ethernet. The most important capabilities of ATM are its seamless connection between WANs and LANs and its ability to handle real-time traffic. The choice between ATM and Gigabit Ethernet for the LAN should be made on the basis of cost and requirements. An Ethernet LAN may be less costly for an equivalent level of service. It may be satisfactory for most requirements if those applications are IP-based. However, if requirements emerge which cannot be supported in an IP-based LAN, a parallel independent network must be implemented to meet those needs.

5.2 ATM vs. Gigabit Switched Routers (GSR). ATM and GSR compete at both the LAN and the WAN level. GSR is delivering dramatic performance improvements over traditional IP routing technologies. At its simplest level, GSR improves on traditional IP routing with the goal of speeding up TCP/IP network communications. However, GSRs can ONLY support IP-based applications. In the WAN, ATM serves well as a general-purpose technology to support ALL requirements. GSR may be a compelling technology for the LAN, although it shares the limitations of any IP-based technology.

5.3 Table 2 summarizes in tabular form many of the comparisons and assessments made in this article.

Table 2 . Comparing Technologies to Requirements

REQUIREMENT	GIGABIT ETHERNET (LAN ONLY)	GIGABIT ROUTER IP-BASED (LAN/WAN)	ATM (LAN/WAN)
VOICE (DSN) - Circuits - VoIP - VTOA	VoIP ONLY	VoIP ONLY	ALL [Circuit emulation, VOIP (with IWF) and VTOA]
IP DATA SBU (NIPRNET):	YES	YES	YES (with IWF)
IP DATA Classified (SIPRNET):	Packet based encryption LIMITED to Rates Less than 4-8 MB/s	Packet based encryption LIMITED to Rates Less than 4-8 MB/s	YES (with IWF) - IP over ATM with Fastlane Rates to 2.5 GB/s by 2000
DRSN - Circuits - VoIP - VTOA	VoIP ONLY	VoIP ONLY	ALL (with IWF and Fastlane)
VTC - IP-based - ATM-based	IP-based ONLY	IP-based ONLY	ALL - IP-based with IWF - Classified with Fastlane
Circuit Services	NO	NO	YES
STEP/DISN DEPLOYED - IP-Based - Circuit-based - ATM-based	IP- based ONLY	IP-based ONLY	ALL - IP-based with IWF - Circuit-based with IWF - Classified with Fastlane
VPN over WAN (assumed IP-based)	YES	YES	YES (with IWF)
VERY high Speed streaming (IP or ATM-based)	NO	NO	ALL
Native ATM service	NO	NO	YES
High Speed Classified	NO	NO	YES
Quality of Service - IP-Based - ATM-based	Limited IP-based (e.g. RSVP, Differentiated Service)	Limited IP-based (e.g. RSVP, Differentiated Service)	YES - Application-specified - IP-based using IWF
Guaranteed Connectivity	NO (approximation)	NO (approximation)	YES

6. CONCLUDING THOUGHTS

6.1 A Basis for choice of ATM. Each of the technologies discussed here is complementary and has a legitimate place in the end-to-end DISN. DISA is aggressively pursuing the introduction of ATM as the technology of choice for the DISN CORE (backbone) for the following reasons:

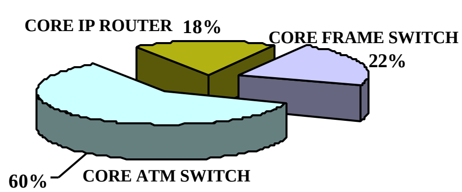
6.1.1 IP is not the only thing out there. It is widely recognized that IP is the dominant protocol for network users today. However, the full range of requirements for the DOD encompasses high performance applications that do not or cannot use IP. One of these requirements is high-speed classified data. Current IP-based network encryptors such as the Network Encryption System (NES) and the Taclane can support IP data at rates only up to 4-6 Mbps. Many intelligence and information dissemination missions require effective transmission rates of classified information at 30-1000 Mbps. The ATM-based Fastlane (KG-75) is the only current technology that can meet this critical need. Other non-IP based applications include synchronous (streaming) applications such as video where timing information is vital and native ATM applications. Given this need for a multi-service integrated system to support the warfighter, ATM is the best technology for the CORE.

6.1.2 DISA is following the same technology path selected by the commercial sector. In a recent Forrester Survey of 30 Domestic and International Carriers and 20 Telecom Equipment Vendors, it was revealed that:

- 97% of those surveyed plan to build or already have a multi-service network
- 80 % of the Carriers intend to use ATM as the foundation technology [†]

Also, a recent Data communications technology forecast projected ATM to dominate in Core Carrier

1999 Core Carrier Data Switch Revenues
(worldwide, projected $7.8 billion)



Source: Datacommunications

Revenues For 1999

6.1.3 The selection of ATM as the enabling CORE technology for the DOD Enterprise is based upon nearly a decade of collaborative research and development with industry and other DOD advanced technology centers such as DARPA and the Naval Research Laboratories. Much of the applied knowledge being delivered to the DOD has been born out of the "Living Laboratory" of the Advanced Technology Demonstration Network (ATDNet) and similar high technology research efforts. All of

[†] VOP Summit Brief, "Voice and Packet Networks", David Misunas, Vice President, Ascend, 25 February 1999

these consensus-building endeavors are focused on developing a viable and affordable "Global Grid" infrastructure that can meet all needs of the warfighter for years to come.

6.1.4 Bandwidth constraints force integrated solutions. The DOD is in a unique environment when it comes to supporting the tactical deployed warfighter. One constant aspect of deploying forces to remote locations around the world is that there is never enough bandwidth. Current networking approaches require portions of this scarce resource to be dedicated to various applications. Reallocation of bandwidth is a time-consuming and often disruptive challenge. ATM holds the promise of being able to allow ALL applications to compete for bandwidth in real-time and to have bandwidth allocated based upon user and mission priorities.

7. THE WAY AHEAD.

We conclude this article with some observations and recommendations.

7.1 In this comparative look at several advanced networking technologies, it is clear that each of them has a vital place in the Global Grid infrastructure for the DOD.

7.2 It is clear that DISN services must evolve to exploit the advantages of network-centric services and migrate from their current dedicated stand-alone (stovepipe) architecture. DISN services must be able to share bandwidth on demand within a single, cost-effective Wide Area Network.

7.3 The CORE DISN WAN MUST be ATM-based to meet ALL requirements.

7.4 Local Area network designers and managers must make informed and best value decisions concerning their choice of a LAN technology.

Figure 5 summarizes many of the technical and architectural approaches to an integrated DISN which supports information services to the warfighter. It illustrates the point that there is a place in the DISN for all types of technology, some of which have been described in this paper.

DISA recognizes the value of and encourages the use of new technologies such as Gigabit Ethernet and Gigabit Switched Routers. They are most appropriate in Campus and/or tactical LAN environments that need to support only IP-based applications. DOD CINCs, Services and Agencies may find that these technologies are a cost-effective solution to their LAN requirements. As with any major engineering decision, the choice of technology should be made based on a judicious combination of business and technical factors. In the final analysis, technology selections must support the needs of the DOD enterprise. It is DISA's job to find the right solution to the business problem.

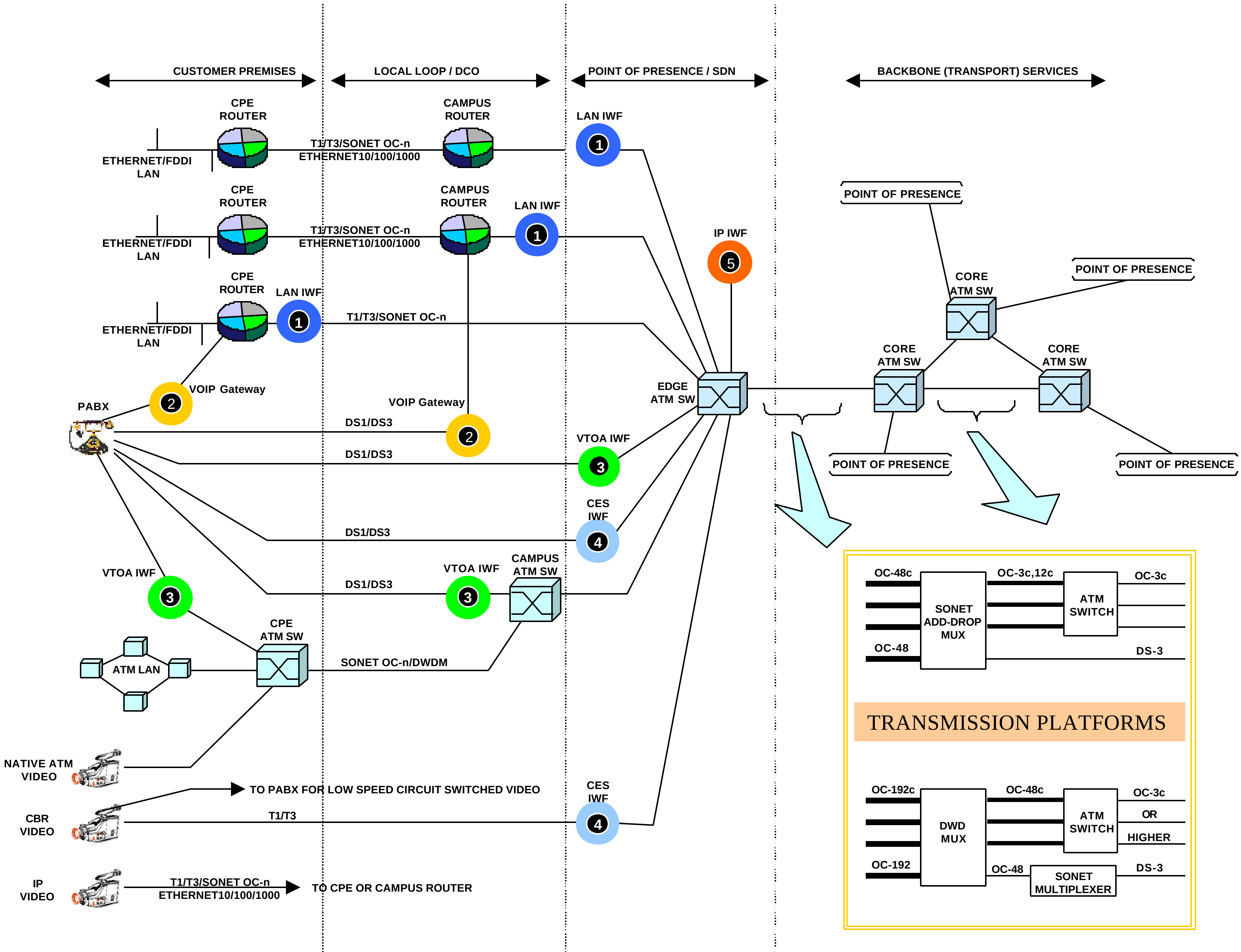
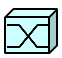


Figure 5. Integrated DISN Architecture

Figure 5 Legend

LAN IWF	1	LAN Interworking Function (IWF). (1) Converts from physical LAN interface (e.g., Ethernet, FDDI) to ATM. (2) Provides IP over ATM intertnetworking (e.g., LANE, MPLS, MPOA) NOTE: May be separate device, integrated with router or integrated with ATM switch.
VOIP Gateway	2	Voice over IP Gateway. (1) Terminates and originates telephone calls from/to traditional telephony systems (e.g., PABX). (2) Converts voice into IP. May be separate device, intagrated with PABX or integrated with router.
VTOA IWF	3	Voice Telephony over ATM Interworking Function. (1) Terminates and originates telephone calls from/to traditional telephony systems (e.g., PABX). (2) Converts voice into ATM
CES IWF	4	Circuit Emulation Service Interworking Function. Converts legacy circuits (e.g., DS-1, Synchronous EIA530, etc) into Constant Bit Rate (CBR) ATM
IP IWF	5	IP Interworking Function (IWF). (1) Provides IP over ATM intertnetworking (e.g., LANE, MPLS, MPOA)
		Router. Accepts IP data from access network; passes it to ATM switch via IWF or to higher level router. May be traditional, Gigabit Switch Router (GSR) or IP switch
		ATM Switch. Switches ATM cells at access area or across core
		SONET Add-Drop Multiplexer (ADM): Shunts lower speed copper and fiber circuits onto and off high speed logical ring
		Dense Wave Division Multiplexer (DWDM): Muxes high speed fiber connections onto single fiber cable